Improving QoS Of WiMAX By On_Demand Bandwidth Allocation Based On PMP Mode

ZhenTao Sun[1], Abdullah Gani[2], XiuYing Sun[3], Ning Liu[1]

[1] Land &Environment College, ShenYang Agricultural University,
110161 ShenYang City, China, zhentaosun@hotmail.com

[2] Faculty of Computer Science & Information Technology, University of Malaya,
50603 Kuala Lumpur, Malaysia, abdullahgani@gmail.com

[3] Liao Ning Agricultural Technology School 110866 ShenYang City, China, s1205s@hotmail.com

***Abstract*—The bandwidth allocation in both wired and wireless networks has posed great challenges to network engineers for improving desirable Quality of Service (QoS), Bandwidth allocation is always an important element for improve QoS of network. Despite this, IEEE 802.16e-2005 does not have a bandwidth allocation algorithm or mechanism to support (worldwide interoperability for microwave access) WiMAX network presently. This includes both uplink (UL) and downlink (DL) directions. Thus, most of researches are focusing in this area. In order to improve the QoS of WiMAX demand, the total capacity of WiMAX system must be optimized. Thereby, in this research, a new bandwidth allocation mechanism for WiMAX network is proposed, called On Demand Bandwidth Allocation (ODBA). The proposed mechanism design has the management module in the Subscribe Station (SS), which is for management UL bandwidth, and one new module in the Base Station (BS). This includes UL/DL bandwidth allocation and service flow schedule. We tested the new mechanism by running in the simulation of OMNET++. As the results show that the ODBA mechanism has improve the scheduled probability (SP) and increase the throughput of WiMAX network.**

***Index Terms*—IEEE802.16e; Throughput; Scheduled Probability; Service Flow; Mechanism; Bandwidth Allocation; WiMAX**

I. Introduction

WiMAX system can cater for both fixed wireless and mobile wireless alternatives, as compared to conventional DSL and cable Internet. It is described in IEEE 802.16-2004 Wireless Metropolitan Area Network (MAN) standard.

A. WiMAX System

Typically, a WiMAX system consists of two parts: Base Station (BS) and Subscriber Station (SS) (Figure1). BS consists of outdoor electronics and a tower which can cover up to 50 km in theory. However, one BS in normal practical consideration can only cover up to 10 km radius usually. Thus any wireless node within the coverage area would be able to access the internet.

Mobile WiMAX enables convergence of both mobile and fixed broadband networks. It is a broadband wireless solution technology based on a common base feature of wide area broadband radio access and flexible network architecture. The mobile WiMAX organization supports OFDMA technique in the NLOS environments.

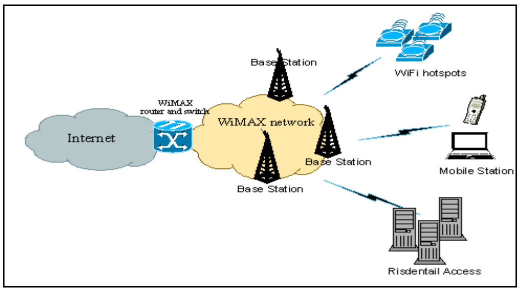

Figure 1: WiMAX Network Infrastructure

B. WiMAX Technology

The WiMAX technology developed based IEEE 802.16e-2005[12], is capable of providing network access to buildings through external antennas connected to radio Base Stations (BSs). The frequency bandwidth coverage is within the range from 2 to 66 GHz. This technology operates in two operational modes, defined by the MAC layer - Point to Multi-point (PMP) and Mesh Mode. PMP is a centralized architecture where all the traffics between subscriber stations (SSs) and base station (BS), are controlled by a BS.

Traffic direction is used to distinguish two types of data channels: uplink (UL) channel where the data is sent from the SS to the BS, and downlink (DL) channel where the burst data is sent from BS to SS. In both modes, MAC layer is designed to support quality of service (QoS) in order to enhance the performance parameters in terms of bandwidth utilizing, latency, jitter and reliability to the end users. Besides, strong QoS is also supported through classification of different service flows and fixed-size real-time service flows through UL scheduling.

Numerous researches have been conducted with the objective to improve the performance of WiMAX bandwidth allocation. Some proposed research works will be discussed as follows: In [1], A protocol is the UBAR (Uplink Bandwidth Allocation and Recovery) will be discussed. In this protocol, the proportional fair scheme is employed to utilize the bandwidth efficiently. It also adopts the timeout-based UL-MAP retransmission scheme with uplink bandwidth reallocation algorithms to simultaneously solve three bandwidth waste problems. In

doi:10.4304/jcp.6.10.2187-2195

[2], through the research, a grant allocation algorithm – Half-Duplex Allocation (HDA), is proposed, to ensure a consistent and feasible grant allocation while satisfying the sufficient conditions. The research shows that from the application of HAD, the delay of real-time and non real-time interactive traffic for both SS and half-duplex, and full-duplex SS are almost equivalent. However, it is not an efficient bandwidth allocation scheme as it has a lower throughput. In [3], the adaptive bandwidth allocation scheme (ABAS), is adopted to adjust the bandwidth ratio according to the current traffic profiles. The aggregate throughput is higher, but it does not take into consideration of the service flow priority and fairness. Hence, the adoption of this scheme will cause the starvation service flow. In [4], the PDFPQ (Preemptive Deficit Fair Priority Queue) scheme is proposed, which is enhances the QoS requirements of real time polling service (rtPS) flow class, decrease the delay time, and improve the throughput as well. The HUF (Highest Urgency First) algorithm proposed in [5], is modulation aware, while further satisfying the latency guarantee, service differentiation and fairness. The setback of this is its inability of long term service flow scheduling. In [6],[7],[8], the physical-layer characteristics such as MCS are not taken into consideration, and in [9], the solution scheme is ignored and starvation can easily occur for the low-level service.

As discussed before, the past researches mostly focus on part of the conditions of WiMAX network. Some of the researches carried out are to improve the system throughput; some of the researches found out the methodology to improve the different SF fairness. However, none of the researches propose a mechanism or algorithm for on demand bandwidth allocation based on PMP mode in WiMAX network. Thereby a new mechanism On Demand Bandwidth Allocation (ODBA) for WiMAX network will be proposed in this research paper.

The aim of this research is to resolve the problem of bandwidth allocation in WiMAX network based on IEEE 802.16e-2005. A new mechanism, which allocates the bandwidth on demand, will be presented. The research is organized as following: section II provides a literature review of the proposed mechanism; section III presents a description of the ODBA mechanism model design; section IV we introduce the methodology of our designed model; section V analysis the simulation result data and discussion. We present the conclusions and future works in section VI.

II. Literature Review

In this section, it presents substantial amount of materials for research, and to highlight the issues which are under consideration. This includes the review of some of algorithms and mechanisms, which have been mentioned in previous section, to improve the QoS performance of bandwidth allocation in WiMAX network.

A. IEEE 802.16e-2005 Standard Overview

The IEEE organization allowed the IEEE 802.16e-2005 amendment to the existing IEEE 802.16-2004 [11] standard in December 2005. The IEEE 802.16e-2005 standard is a further development of 802.16-2004, and it is a further expansion of WiMAX in the frequency range up to 6 GHz with the objective of allowing mobile applications and even roaming. This standard includes all the features of IEEE 802.16-2004 as well as additional functionality. The number of carriers can vary over a wide range depending on permutation zones and FFT (Fast Fourier Transform) base (128,512, 1024, 2048). Unchallenged, WiMAX wireless network has proven to be lower cost than fixed cable services, despite the many benefits. The FCH (Frame Control Header) content has been shortened and modified for FFT size 128. This amendment adds the features and attributes to the standard necessary features to support mobility.

The basic characteristics of the IEEE 802.16-2004 and IEEE 802.16e-2005 standards are summarized in Table1. These standards support a variety design options such as Wireless-MAN-SCa which is a single-carrier based physical layer and Wireless-OFDMA (Orthogonal Frequency Division Multiple Access) which is an OFDMA-based physical layer. These designs for MAC operation have many choices in architecture, frequency band, duplex.

Table1: Characteristics of IEEE 802.16-2004 and 802.16e

Parameters	*802.16-2004*	*802.16e*
Frequency Band	2GHz~11GHz	2GHz~11GHz: fixed 2GHz~6GHz: mobileWiMAX
Architecture	PMP, mesh	PMP, mesh
Transmission scheme	Single carrier,	Single carrier, Multiple sub-carriers
FFT	256 or 2048	128, 512, 1024, 2048
Modulation	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM
Multiplexing	OFDM	OFDMA
Application	Fixed NLOS	Fixed and mobile NLOS

B. WiMAX Key Technology

a. Physical Layer Features

WiMAX Forum [10] according to IEEE 802.16e-2005 standard defines the air interface of WiMAX system in Physical (PHY) layer. WiMAX system can use both Orthogonal Frequency Division Multi-plexing (OFDM) and Orthogonal Frequency Division Multi-plexing Access (OFDMA) modulation technology, to effectively provide multi-path access in Non-Line-of-Sight (NLOS) environment. Thus, WiMAX will choose appropriate bandwidth at 1.25~20 MHz, according to the frequency resource and service flow demand. WiMAX Physical layer adopts to TDD mode, to choose proportion frame for Uplink and Downlink direction according to the different service demand.

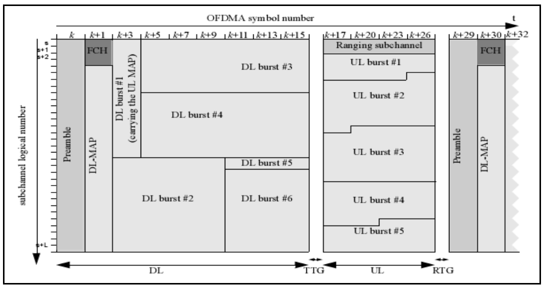

Figure 2: WiMAX OFDMA Frame Structure [10]

WiMAX network designs for TDD implementations are less complex and therefore, incur lower cost. OFDMA frame structure for a Time Division Duplex (TDD) is designed in a way that each frame be divided into UL and DL sub-frames separately, to prevent UL and DL transmission collisions by Transmit/Receive and Receive/Transmit Transition Gaps (TTG and RTG respectively) in a frame. The OFDMA frame structure based on TDD is illustrated in Figure 2.

b. MAC Layer Features

In WiMAX MAC system (Figure 3), it illustrates the connections and data services flow to transmit various control signal and user data between the BS and SS. At one end, the system utilizes the service flow to provide the QoS parameters (including rate, delay difference, etc.) for different quality requirements, in order to provide better service. At the other end, the MAC layer utilizes the connecting service to realize the resource management. During the connections, the system realizes the transmission, through the correlation between service flow and network connection for the upper and downward service requirements and MAC layer.

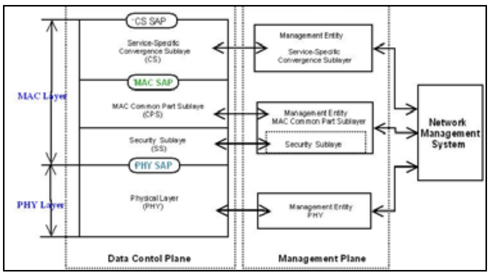

Figure 3: IEEE 802.16e MAC Structure

In order to provide efficient channel access control mechanism, the MAC layer is defined by IEEE 802.16e-2005 protocol for control mechanisms, mainly includes service, access control part convergence, ranging, link scheduling, and optional automatic retransmission mechanism. IEEE 802.16e-2005 MAC layer is divided into three sub-layers from high to low:

- CS (Service—Specific Convergence Sub-layer) Located at the top of the MAC CPS. The MAC SAP obtains service provided by MAC CPS and it provides services for the upper layer by CS SAP.
- CPS (Common Part Sub-layer) provides MAC layer core functions, such as system access, initialization, bandwidth allocation or request connection and keep or release etc.
- SS (Security Sub-layer) is an independent safety sub-layer which provides certification, key exchange and encryption, etc.

C MAC layerScheduling Mechanism

The BS depends on the uplink and downlink scheduler to achieve the scheduling of efficient data flow services. Based on the Uplink upward direction, Uplink scheduler controls the Uplink wireless channel distribution and utilization, and it decides which wireless bandwidth etc for the users. In Downlink direction, Downlink scheduler controls the Downlink bandwidth allocation of resources utilization, and decides the way to distribute and limit the resources. This also shall satisfy the different service flows and demand of QoS.

a. Uplink scheduler

Uplink Wireless resource is allocated by the specific Uplink upward scheduling algorithm of the Uplink scheduler. The uplink scheduler mechanism quality is the key factor in the Uplink channel utilization. The QoS parameters and channel quality parameters of scheduling are connected using the Uplink scheduling algorithm reasonable distribution and transmission bandwidth for each terminal. The distribution results through UL-MAP will notify all radio terminals. This is performed by the Uplink scheduler according to various terminal bandwidth requests. The terminal scheduler will grant Uplink bandwidth to each service flow correspondence Uplink connection to ensure the quality of service.

b. Downlink scheduler

The downlink scheduler wireless resources allocation is based on the frequency domain, time domain and the users etc. In time domain, the downlink scheduler needs to have choice when sending the data. While in frequency domain, the downlink scheduler needs to choose to send data in the choice of channels. In the user domain, downlink scheduler bandwidth allocation must satisfy the requirements of the service flow QoS.

In this paper, the scheduling algorithm does not take into consideration of the dynamic selection channels in frequency domain, and the channels that have similar transmission power. In order to simplify the scheduling algorithm, the Downlink scheduler will only emphasis on the time gap, and choice of the service flow required to decide the volume of data transmitted for this service flow. The scheduler downlink is designed under certain challenges: under the condition of the fairness to satisfy service flow quality of the QoS requirements, and to improve the system throughput. In addition, it needs to take into consideration of the process scheduling in a frame for completion, to achieve simplicity and efficiency.

III MODEL DESIGN

A. Bandwidth Allocation Model Requirements

a. Ranging

OFDMA Physical layer adopts binary phase-shift keying (BPSK) modulation state for sending 144 bits

Code Division Multiple Access (CDMA) code for initial ranging. After BS receives RNG-REQ (Ranging Request) CDMA code, BS will send RNG-RSP (Ranging Response) and UL-MAP messages to terminal through broadcast. UL-MAP message includes CDMA allocation IE, which describes the specified UL channel that sends RNG-REQ message by terminal. If SS does not response and does not send acknowledgement (ACK) message feedback, then BS will increase power to broadcast RNG-RSP until receiving the ACK message from SS. After that, terminal will adjust the frequency, time and power for synchronization with BS, according to the RNG-RSP message. In initial ranging process, BS will choose suitable Downlink Interval Usage Codes (DIUCs) according to Carrier Interference and Noise Ratio (CINR) of DL direction, and suitable Uplink Interval Usage Codes (UIUCs) according to CINR of UL direction.

WiMAX ranging process includes 4 types of ranging code: initial ranging code、period ranging code、handover (HO) ranging code and bandwidth request (BR) ranging code respectively. The different ranging code has different function, as shown in table 2. Before SS and BS data transmits, BS and SS are required to establish a logical connection by initial ranging. After that, while BS and SS data transmitting, WiMAX system requires period ranging for dynamic adaptive signal power between BS and SS. When a SS moves into another BS zone, SS needs HO ranging to establish a new connection with the new BS. During the communication between BS and SS, BR ranging is required for dynamic bandwidth request.

Table 2: Different Ranging Coded and Function

Code Type	Function
Initial ranging code	Establish connections between BS and SS
Period ranging code	BS and SS Keep contact
HO ranging code	Establish connection between SS and BS.
BR ranging code	SS send request to BS

b. Service Flow Management of WiMAX System

WiMAX supports vary data services flow with different QoS requirements. In order to have the best controlled bandwidth allocation of the WiMAX network, IEEE 802.16e-2005 standard defines 5 types of service flow as following: UGS (Unsolicited Grant Service), rtPS (Real-Time Polling Service), ertPS (Extended Real-Time Polling Services), nrtPS (Non-Real Time Polling Service) and BE (Best Effort).

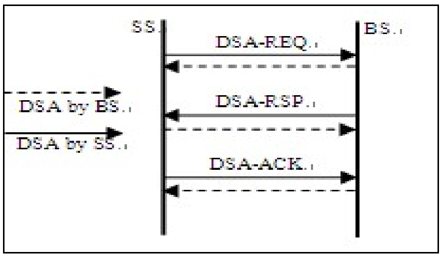

Figure 4: DSA Request by BS or SS

Moreover, Service flow can be dynamic addition、dynamic change and dynamic deletion in MAC layer. Dynamic means that these operations can be processed while BS and SS are communicating, and it can not be created before establishment of communication. The dynamic service flow can be created by either BS or SS. The dynamic service addition request (DSA-REQ) message which is created by BS or SS, includes a service flow Identifier (SFID) of UL or DL direction, a connection Identifier (CID) which is associated with it, and a group of QoS parameters of admitted or activated service flow. The DSA process of UL/DL direction is shown in figure 4.

c. QoS Parameters Class

QoS parameter class is a parameter group, which is describes a service flow, such as maximum delay, tolerant Jitter and Minimum Reserved Traffic Rate etc. Normally, a service flow has three levels of class: preparative QoS parameters class, admitted QoS parameters class and activated QoS parameters class.

The three QoS parameters class in a service flow, satisfy the following conditions:

- activated QoS parameters class is a subclass of admitted parameters class,
- admitted QoS parameters class is a subclass of preparative parameters class. It is shown as table 3:

Table 3: A Service Flow QoS Parameters Class Relation

state	QoS parameters
Preparative	{A, B, C …, Admitted { }, Activated { }}
Admitted	{A, B, C …, Admitted {A,B,…}, Activated { }}
Activated	{A,B,C…,Admitted{A,B,…},Activated{ A,B,…}}

Here, A、B and C … represent service flow QoS parameters.

B Model Characteristics

A new mechanism ODBA is proposed, not only to improve QoS of WiMAX network, but also to achieve the on demand bandwidth allocation. The model designed focus on MAC layer which includes two scenarios.

Scenario 1. Using Hierarchical Management, in WiMAX system, BS allocates bandwidth resource to UL by SS unit. In DL direction, BS allocates bandwidth according to the QoS demand of different service flow. The BS will calculate the total bandwidth of DL/UL requirement respectively. Then admission control will allocate the sub-carriers for DL/UL used, according to the proportion of DL/UL required total bandwidth.

Scenario 2. According to the HARQ probability, choose the different Adaptive Modulation and Coding (AMC) state for the different SF. This scheme is proposed to improve the WiMAX ratio and efficient usage of bandwidth resource. In this strategy, the AMC is adjusted dynamically based on the different service flow QoS and available bandwidth size.

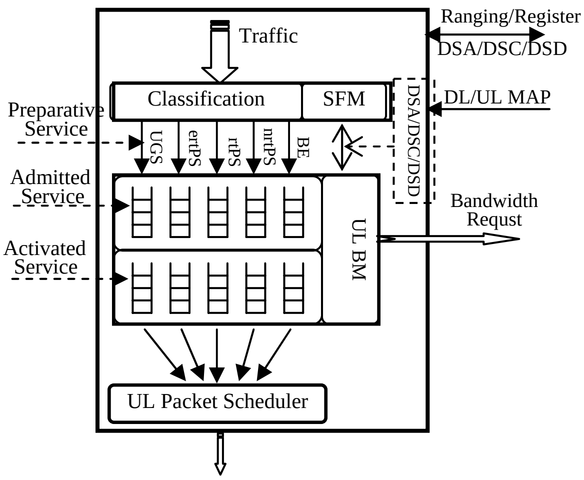

Figure 5: ODBA Mechanism MAC Structure of SS.

The ODBA MAC detailed structure is illustrated in Figure 5. After the BS and SS establish connection, UL bandwidth will be managed by SS.

IV. Methodology

There are two new modules be added in SS, it is Service Flow Management (SFM) module and UL Bandwidth Management (ULBM) module respectively. The terminal does not send the bandwidth request message based on every service flow connection. The ULBM will calculate the total UL bandwidth of all of the services flow required, and then send the bandwidth request message to BS. After the SS receives the message of granted UL bandwidth by BS, the SS will allocate UL bandwidth according to the different service flow QoS demand. The SFM module is responsible for the dynamic service flow management. It sends DSA/DSC/DSD request message to ULBM and the ULBM will feedback a response message to SFM according to the UL bandwidth size. Finally, the activated service flow will be scheduled by the UL scheduler, and the scheduler will adjust the AMC state dynamically according to the granted UL bandwidth size and HARQ.

In UL direction, because bandwidth allocation is by SS unit, so the SS does not need to send every bandwidth request message for every service flow. Thus it can decrease UL spending of bandwidth resource which by it only sends bandwidth request message occupied. And decrease the competition interference of different sub-carriers which are for send bandwidth request message of BE and nrtPS service flow.

In both BS and SS, for the UGS service flow, admitted and activated states are adopted at once. This means that when the UGS service flow is admitted, it will be activated service at once, and be scheduled by scheduler. The scheduling queue order by EDF (Earliest Deadline First) algorithm is for the ertPS and rtPS service flow, while by HRN (Highest Response ratio Next) algorithm is for the nrtPS and BE service flow. In WiMAX system, the different service flow has different priority, they are ordered by as UGS>ertPS>rtPS>nrtPS>BE. The RRWF (Round Robin Weighted Fair) algorithm in scheduler is adopted, for scheduling the different service flow.

Because UGS service flow transmits data by fixed rate for the QoS required, the QPSK state can be adopted to satisfy the QoS demand. As the real time (rtPs, ertPS) and not-real time (nrtPS, BE) service flow can adjust the transmission rate, hence, the QPSK 、 16QAM and 64QAM from lower rate to higher rate can be adopted as well. The real-time service flow requires a guarantee for maximum latency, thus we adopt modulation and coding state from lower rate to higher rate, if we continue receive two HARQ data request, then we decrease one grade; after we continue send 10 frames success, then we can increase one grade of modulation and coding state. Otherwise, the nrtPS and BE service flow need not guarantee maximum latency, so we adopt modulation and coding state from higher rate to lower rate, the modulation and coding rate increase or decrease grade condition same real-time service flow.

V. Data Analysis And Discussion

Throughput refers to the MAC layer, which is the throughput of statistics in BS side. Two values namely peak throughput and average throughput are calculated to evaluate the performance of throughput with ODBA. The peak throughput includes three parameters: UL peak throughput, DL peak throughput and DL/UL peak throughput of different proportion respectively.

A Throughput

Three times of simulation are conducted. First, BS just receives data from all of SS in order to know the UL peak throughput from the simulation result data. Secondly, BS just sends data to SSs, so the DL peak throughput will be known. Lastly, both BS and SS send data according to the DL/UL bandwidth request proportion.

a. UL peak throughput

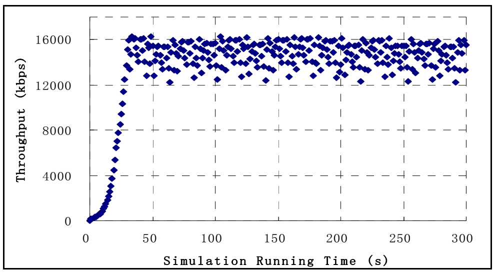

Figure 6: ODBA Uplink Throughput

The UL throughput result data is shown in figure 6. From the graph above, the UL throughput is increasing rapidly, the UL peak throughput occurs at around 34s and the value is 16251 kbps. Since that point, the throughput is always fluctuating which ranges between 16000 kbps and about 12000 kbps.

b. DL peak throughput

The DL throughput simulation result data is shown in figure 7. It shows that the DL throughput is increasing fast, and DL peak throughput occurs at around 23s, the value is 31421 kbps. The DL throughput is fluctuating as well, after simulation run about 23s. The throughput fluctuation ranges between 31000 kbps and about 25000 kbps.

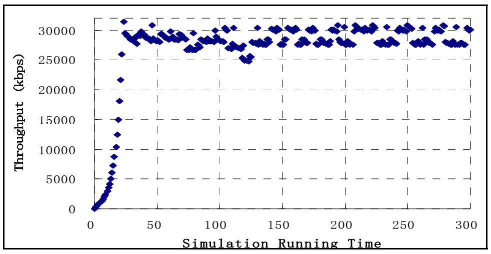

Figure 7: ODBA Downlink Throughput

c. DL/UL Peak Throughput With Different Bandwidth Request Proportion

When DL direction and UL direction have different bandwidth request proportion, the DL/UL peak throughput will be different. In order to evaluate the performance of WiMAX network better throughput with ODBA, the simulation result data is collected while DL/UL has different bandwidth request proportion. The result is shown in figure 8. From this figure, it is shown that when DL/UL bandwidth request proportion is 1: 0 or 0: 1, the peak throughput will be similar to DL peak throughput or UL peak throughput. With DL/UL direction bandwidth request proportion changed, the DL/UL peak throughput is changed as well. Both DL and UL peak throughput are increasing with bandwidth request proportion changing to greater. In reverse, the DL/UL peak throughput is decreasing with bandwidth request proportion changing to smaller.

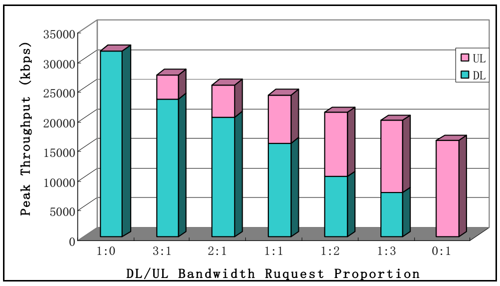

Figure 8: DL/UL Peak Throughput

d. Performance Of ODBA Peak Throughput

Peak throughput is a good metric for comparative purposes. It is able to identify the peak throughput of different DL/UL ratio without adopting ODBA mechanism from paper [10]. Thus the comparison of ODBA and without ODBA result is shown in figure 9 which describes the performance of DL direction peak throughput. Figure10 describes the performance of UL direction peak throughput.

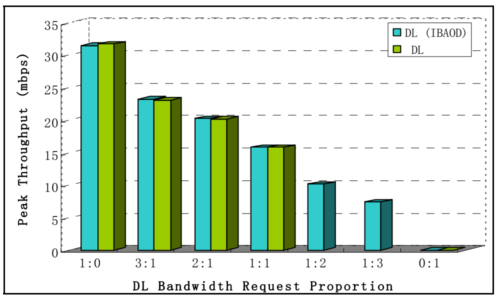

Figure 9: DL Peak Throughput Performance

As shown in figure 9, the DL peak throughput with ODBA and without ODBA has small differences. When DL/UL ratio is 1: 0 and 1: 1, ODBA peak throughput is slightly lower than without ODBA peak throughput. When DL/UL ratio is 3: 1 and 2: 1, ODBA peak throughput is slightly higher than without ODBA peak throughput. The simulation conducted also considers DL bandwidth request size lesser than UL bandwidth request size situation. It is assumed that the DL/UL ratio is 1: 2 and 1: 3 while the DL peak throughput is 10.17 Mbps and 7.42 Mbps respectively.

ODBA peak throughput is not always higher than without ODBA peak throughput in different DL/UL ratio situation. However, as understood, the situation which the DL/UL ratio is 1: 0 or 1: 1, rarely occurs in reality in WiMAX network. In WiMAX system, most of DL/UL ratio is close to 3: 1 or 2: 1. Hence, ODBA performance of DL peak throughput is better than without ODBA system.

From figure 10, it is known that the UL peak throughput with ODBA is higher than without ODBA, in all DL/UL ratio situations. ODBA peak throughput is slightly higher than without ODBA, while DL/UL ratio is 3: 1. When DL/UL is 0: 1, ODBA peak throughput is higher than without ODBA. Furthermore, ODBA mechanism is allocating bandwidth dynamically according to the DL/UL bandwidth request ratio, hence, it can increase utilization of bandwidth resources. The overall performance of UL peak throughput is better with ODBA as compared to without ODBA system.

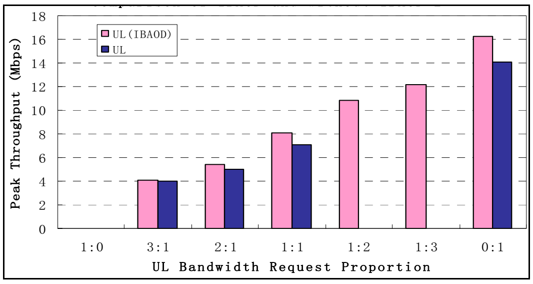

Figure 10: UL Peak Throughput Performance

e Average Throughput

According to the research paper [13], it is able to know the average throughput of WFQ, RED, RIO, FQ, DRR and Drop schedule algorithms in WiMAX system. The comparison of different algorithm average throughput is shown in figure 11. From figure 11, the ODBA average throughput is obviously higher than other scheduling algorithm. As ODBA mechanism applied in different SF will have different characteristics, it is important to adopt the suitable algorithm for different SF queuing, so that the DL/UL scheduling algorithm can improve the lack of different SF queuing algorithm. As proven and discussed, ODBA mechanism has high scheduled probability of service flow, lower queuing delay time (see above section) and dynamic allocation of bandwidth resource. Thereby, ODBA bandwidth performance of average throughput is better than other scheduling algorithm.

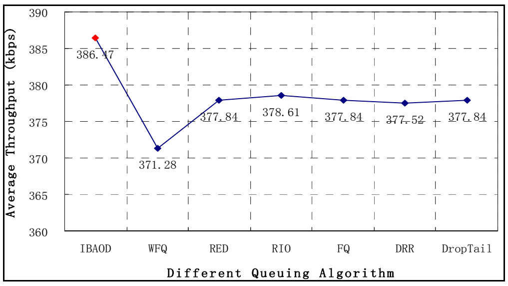

Figure 11: Different Algorithm Average Throughput

B Scheduled Probability (SP)

With the adoption of the new mechanism ODBA in WiMAX system, the fairness of different SF will be discussed. Different service flow will be used to evaluate the packet size scheduled probability (SP). The results from the two directions: UL direction and DL direction will be evaluated.

a. UL Service Flow Scheduled Probability (SP)

After the simulator runs for 100 seconds adopting the simulation scenario one, the different service flow uplink SP will be calculated by the simulation result data. The SS different SF average SP result is shown in figure 12.

Through the graph, it is clear that all the SF can be scheduled before and at approximately 24s in the simulation running time. After that point, the different SF will have different SP. SP of UGS will decrease slowly as compared to other SF, and BE will decrease even at a faster rate. Along with the simulation time, SP of all the SF decreases, and when UGS reaches the biggest SP, BE will have the lowest SP. Furthermore, SP of ertPS is close to UGS, SP of nrtPS is close to BE, SP of rtPS is in the median of SP.

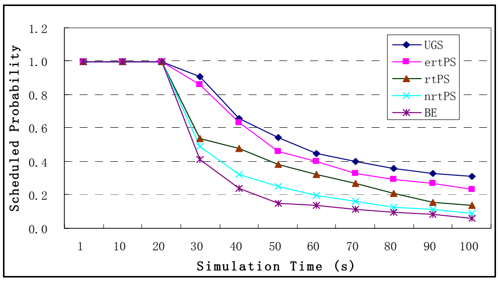

Figure 12: UL Service Flow SP With ODBA

The simulation results satisfy all the rules of different SF schedule priority. When SS sends data size less than the network UL throughput bottleneck size, SP of all the SF is 1. When the SS sends data size more than network UL throughput bottleneck size, SP of different SF will decrease. Finally, when SS sends the optimal data size more than the network UL throughput bottleneck size, the lowest SP of BE can still be scheduled. Even if SP is minimum, there is no starvation of SF occurs in WiMAX system.

b. Comparison of UL Scheduled Probability (SP)

The simulation result data was first obtained without adopting the ODBA mechanism. Then, the data generated by adopting ODBA mechanism, is compared to the data without adopting the ODBA mechanism condition. This is to evaluate the fairness of different service flow. Figure 13 shows the compared result.

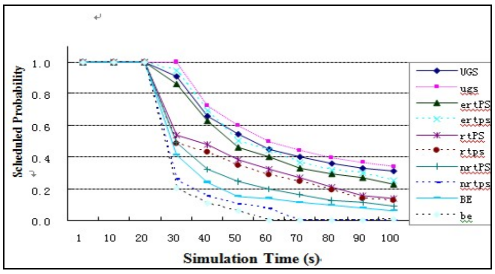

Figure 13: Comparison SP of UL Direction With ODBA and Without ODBA

As shown in figure 13, the ODBA service flow are UGS, ertPS, rtPS, nrtPS and BE, otherwise, ugs, ertps, rtps, nrtps and be means the result of without ODBA service flow. From the graph, it is shown clearly that after SS sends data size more than the network UL throughput bottleneck, SP of ugs and ertps will be more than SP of UGS and ertPS; SP of rtps, nrtps and 'be' are less than erPS, nrtPS and BE. At the simulation time around 60s, the SP of 'be' and nrtps is 0, which means that the starvation of SF has occurred in WiMAX system.

In comparison of SP with ODBA and without ODBA through figure 6.2, it is known that when SS sends packet size more than the network UL throughput bottleneck, SP of rtPS, nrtPS and BE will decrease slowly in contrast to rtps, nrtps and be. Even though the SP of UGS and ertPS is less than ugs and ertps, the performance of all the SF with ODBA mechanism is better than without ODBA mechanism in WiMAX system. The reason for this is that the ODBA mechanism considers the fairness of different service flow more than without ODBA mechanism. It can avoid starvation of SF occurs under condition of SS requests more UL bandwidth. Thus ODBA mechanism can improve the fairness of different service flow in WiMAX system.

c. DL Service Flow Scheduled Probability (SP)

The DL direction service flow of SP, and the BS of different SF and the average SP result is shown in figure 14. From the graph, all of the SF can be scheduled before and at around 46s. After that point, the SP of different SF is different. The DL direction service flow SP of UGS, ertPS, nrtPS and BE is similar as the UL direction.

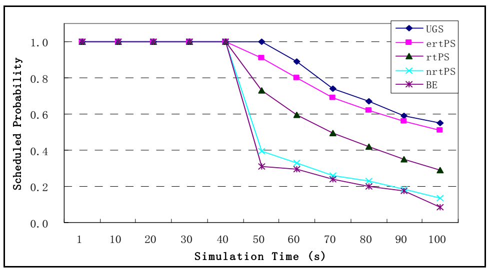

Figure 14: DL Service Flow SP With ODBA

As BS sends packet size which is less than the network DL throughput bottleneck size, the SP of all the SF is 1. While the BS sends data size more than the network DL throughput bottleneck size, SP of different SF will decrease. Otherwise, when BS sends the optimal packet size more than the network DL throughput bottleneck size, SP of BE and nrtPS service flow are insignificant. When the SP is minimum, it means that the BE and nrtPS service flow can still be scheduled, and no starvation of SF occurs in WiMAX system.

d. Comparison of DL Scheduled Probability (SP)

The simulation result data of both with ODBA mechanism and without ODBA mechanism is compared, for the purpose of evaluating the fairness of DL direction different service flow. The compared result is shown in figure 15. The UGS, ertPS, rtPS, nrtPS and BE, means ODBA service flow SP, and the ugs, ertps, rtps, nrtps and be means the without ODBA service flow. From the graph, after the BS sends packet size more than the network DL throughput bottleneck, SP of ugs and ertps will be more than SP of UGS and ertPS; SP of rtps, nrtps and 'be' will be less than erPS, nrtPS and BE. At the simulation time of around 80s, the SP of 'be' and nrtps has decreased to 0, which means that the starvation of SF has occurred in DL direction.

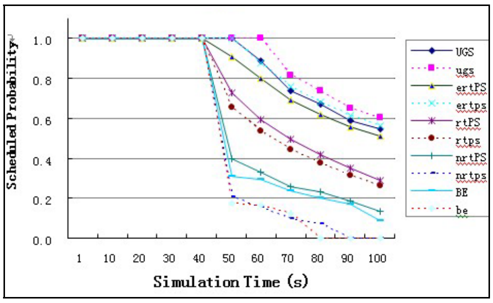

Figure 15: Comparison of DL SP With ODBA and Without ODBA

In comparison of DL direction for different service flows of SP, between with ODBA and without ODBA as illustrated in figure 15, when BS sends packet size more than network DL throughput bottleneck, SP of rtPS, nrtPS and BE will decrease slower than rtps, nrtps and 'be'. Even though the SP of UGS and ertPS is less than ugs and ertps, the performance of all the SF with ODBA mechanism is better than without ODBA mechanism in DL direction. The reason for this is because the new ODBA mechanism can avoid starvation service flow occurs when DL requires bandwidth more than DL throughput bottleneck size. Thus, ODBA can improve the fairness as compared to without ODBA.

VI. Conclusion

This paper presents ODBA mechanism in WiMAX network. In order to solve the current issues faced in WiMAX network, and improve QoS demand, a new mechanism, ODBA is designed. It is an on demand bandwidth allocation mechanism for WiMAX. ODBA depends on the different characters of different service flow, to adopt different schedule algorithm. Further more, DL/UL direction of different service flow is scheduled by BS and SS respectively. The performance of ODBA mechanism and its behavior are evaluated, analyzed and compared with other algorithms and those without ODBA in WiMAX network. The performance has been simulated using OMNeT++ simulator in metrics of network throughput. The simulation results show that the ODBA mechanism has higher network performance than without ODBA in WiMAX network.

Thus, in future, the related research needs to work on improving the fairness of different SS, and reduce the delay time. In addition, it is important to consider the signal interference and the movement of SS which will affect the bandwidth allocation in mobile WiMAX network.

References

[1] Chou. Z.T, and Lin. Y.H, "Bandwidth Allocation and Recovery for Uplink Access in IEEE 802.16 Broadband Wireless Networks," IEEE, pp. 1887–1891, July 2007.

[2] Andrea.B and Claudio.C, etc, "Bandwidth Allocation with Half-Duplex Stations in IEEE 802.16 Wireless Networks," IEEE Transactions on mobile computing, vol. 6. No. 12, pp.1384–1397, December 2007

[3] Chiang. C.H and Liao. W.J, "Adaptive Downlink/Uplink Bandwidth Allocation in IEEE 802.16 (WiMAX) Wireless Networks: A Cross-Layer Approach," IEEE Globecom, pp. 4775-4779, 2007

[4] Haidar. S and Hassan. A, etc. "New Scheduling Architecture for IEEE 802.16 Wireless Metropolitan Area Network," IEEE, pp. 203-210, 2007.

[5] Lin. Y.N and Wu. C.W, etc, "A Latency and Modulation Aware Bandwidth Allocation Algorithm for WiMAX Base Stations," IEEE WCNC, pp. 1408-1413, 2008.

[6] Kitti. W, and Aura. G, "IEEE 802.16 Based Last Mile Broadband Wireless Military Networks With Quality of Service Support" IEEE, pp. 779-784, 2003

[7] Chen. J.F and Jiao. W.H, etc. "A service Flow Management Strategy for IEEE 802.16 Broadband Wireless Access Systems in TDD Mode", IEEE, pp. 3422-3426, May 2005.

[8] Y. N. Lin, S. H. Chien, Y. D. Lin, Y. C. Lai, M. Liu, "Dynamic Bandwidth Allocation for 802.16e-2005 MAC," Book Chapter of "Current Technology Developments of WiMax Systems," edited by Maode Ma, to be published by Springer, 2007.

[9] Alexander.S, Olli. A, and Juha.K. "Ensuring the QoS requirements in 802.16 Scheduling" MSWiM, Torremolinos, Malaga, Spain, pp. 108-117, October 2006

[10] Mobile WiMAX Part I, "A Technical Overview and Performance

Evaluation," WiMAX Forum, April 2006.

[11] IEEE Std 802.16-2004,"IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems," June 2004.

[12] "IEEE Standard for Local and Metropolitan Area Networks–Part 1 Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendu1," IEEE Std. 802.16e-2005.

[13] "Performance Evaluation For Scheduling Algorithms In WiMAX Network" , International Conference On Advanced Information Networking and Applications. 2008.

ZhenTao Sun was graduated from the University of Malaya, Malaysia. He got his Master degree in Compute Science and Information Technology in 2010. He is now working in ShenYang Agricultural University, China. He has published several conference and journal papers during his study. He is now in the process of pursuing his Phd study.

Abdullah Gani is a Senior Lecturer at the Faculty of Computer Science & Information Technology. His research interest includes Switched Networks (QoS, Traffic Engineering), Soft Computing (Reinforcement learning, Intelligent Agent), Routers Technology (Resource Control), Middleware Technology (Intelligent Middleware), Mobile Computing (Resource control). He received his Bachelor and Master degree from the University of Hull, UK in 1989, 1990 respectively, and his PhD from the University of Sheffield, UK. He has published more than 85 academic papers in proceedings and journals.

XiuYing Sun is a senior lecturer, working in the LiaoNing Agricultural Technology School now, she received her Master degree from ShenYang Agricutural Unviersity in 2004.

Ning Liu is now working in the ShenYang Agricultural University, China. He got his Master degree from YuNan Agricultural University in 2006. And He is now studying Ph.D in ShenYang Agricultural University, China. He has published several conference and journal papers during his study.